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FLOUR-MILL INSECTS AND THEIR CONTROL

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(The Bureau of Entomology and Plant Quarantine in cooperation with the Kansas Agricultural Experiment Station)

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INTRODUCTION

The losses caused by insects injurious to stored grain and milled products are tremendous. It is estimated that in the United States these losses represent about 5 percent of the total value of the products, or about $250,000,000 annually, and this does not take into consideration the reputations of the milling company, the flour broker, and the baker, which suffer when their well-established brands of products are damaged by the presence of insects.

INSECT PESTS OF STORED GRAIN [1]

The greatest source of insect infestation in the flour mill is the grain itself. Therefore, a knowledge of the principal insect pests of stored grain and methods for their control is of vital importance to the miller who wishes to maintain a clean mill and reduce losses from insects to a minimum.

INFESTATIONS ON THE FARM AND THEIR CONTROL

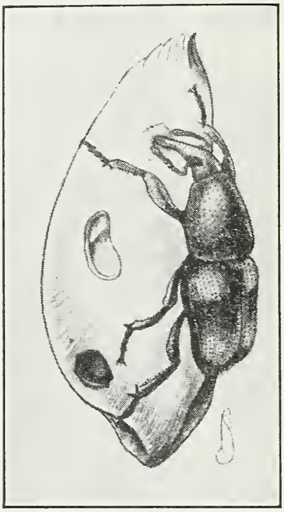

FIGURE 1.—The rice weevil, one of the worst pests of stored grain.

The rice weevil (*Sitophilus oryzae* L.) (fig. 1) and the Angoumois grain moth (*Sitotroga cerealella* Oliv.) (fig. 2), two of the most destructive insects infesting wheat, corn, rice, sorghum, and other cereals, may attack the grain, not only when it is in shock and stack in the field, but also before it is harvested. Particularly in the South, large numbers of these insects fly from grain cribs and bins when the grain begins to ripen in the fields. The eggs that are laid in or on the grain at this time develop into weevils or moths, giving rise to the common but erroneous belief that they are inherent in the germ of grain.

After the grain has been harvested, threshed, and placed in bins on the farm, it may be further infested. Many seemingly clean and empty bins may actually harbor thousands of hungry insects. The larvae of the cadelle (*Tenebroides mauritanicus* L.) (fig. 3, adult; fig. 4, larva) burrow in the woodwork of bins in enormous numbers and may remain there for long periods, only to come out when fresh grain is placed in the bin. It is not uncommon to see newly threshed grain literally swarming with worms a few weeks after being placed in wooden bins.

A common practice on the farm is to store bran, shorts, and other milled feeds in the granary. Occasionally cleanings from the mills, sweepings, or damaged or infested flour and meal may be purchased as cheap sources of feed. These products may harbor such insects as the confused flour beetle (*Tribolium confusum* Duv.) (fig. 5), the rust-red flour beetle (*T. ferrugineum* Fab.) (fig. 6), the saw-toothed grain beetle (*Oryzaephilus surinamensis* L.) (fig. 7), the flat grain beetle (*Laemophloeus pusillus* Schon.) (fig. 8), the rust-red grain beetle (*L. ferrugineus* Steph.), and numerous other pests of grain and milled products which sooner or later migrate to the bins of new grain.

If every farmer would fumigate his grain soon after threshing and would store it away from feeds that might be infested, the insect troubles of the elevator man and miller would be greatly reduced.

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[1] For more detailed information regarding the insect pests of stored grain and their control see the following publications: Back, E.A., and Cotton, R. T. STORED-GRAIN PESTS. U. S. Dept. Agr. Farmers' Bull. 1260, 47 pp., illus. 1922. Back, E. A., and Cotton, R. T. CONTROL OF INSECT PESTS IN STORED GRAIN. U. S. Dept. Agr. Farmers' Bull. 1483, 30 pp., illus. 1926. Copies of these bulletins can be obtained from the Department of Agriculture, Washington, D. C.

Unfortunately, it is not always practicable for the farmer to fumigate, and many who could fumigate do not wish the expense and trouble connected with it. They dispose of their grain as soon as they observe signs of infestation, thus passing on their insect problems to the miller or the elevator man.

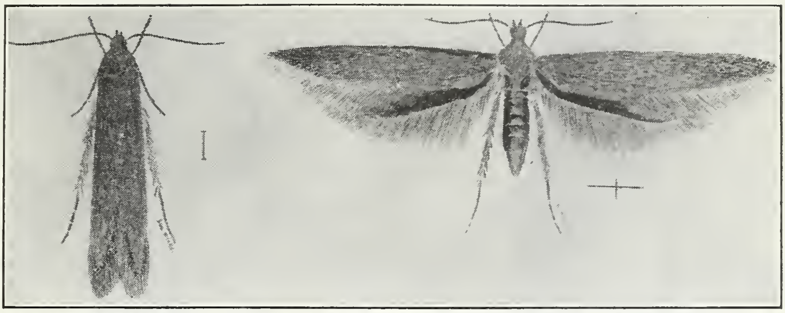

FIGURE 2.—The Angoumois grain moth attacks grain both in the field and in storage.

For the farmer, fumigation with carbon disulphide is the most satisfactory treatment for infested wheat or corn. Carbon disulphide is cheap, effective, readily available, easily shipped, and, if of good grade, has no bad effect upon the grain. Although the fumes of carbon disulphide are inflammable, and are explosive when mixed with air in certain proportions, this fumigant can be handled with reasonable safety if the proper precautions are taken. It is a colorless, volatile

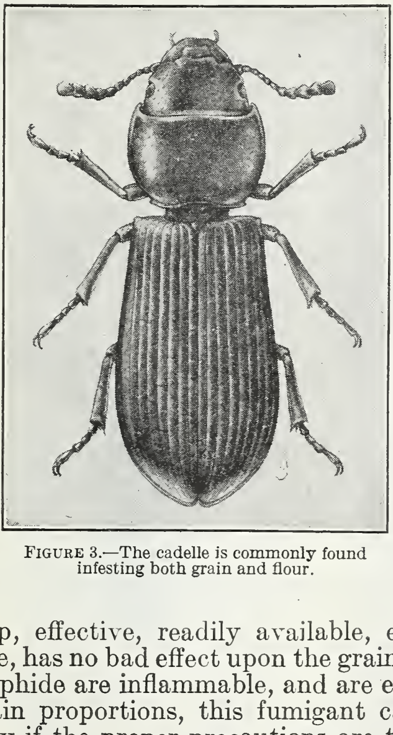

FIGURE 3.—The cadelle is commonly found infesting both grain and flour.

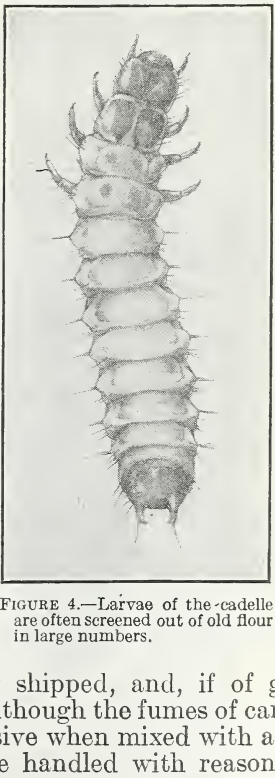

FIGURE 4.—Larvae of the cadelle are often screened out of old flour in large numbers.

liquid which evaporates on exposure to air, forming a gas that will penetrate to the bottom of a grain bin if a sufficient quantity is used. It should be sprinkled over the surface of grain stored in tight bins, in dosages ranging from 30 to 40 pounds per 1,000 bushels of grain,

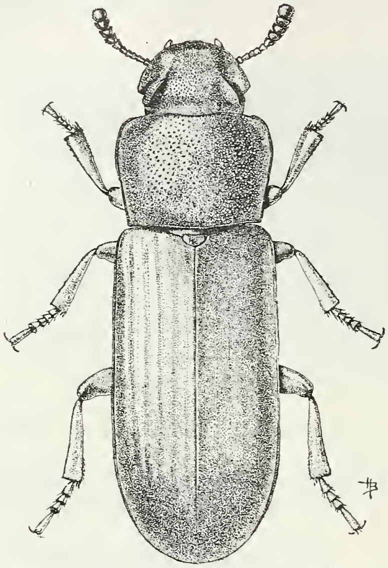

FIGURE 5.—The confused flour beetle is undoubtedly more troublesome in flour mills than any other insect except the closely related rust-red flour beetle.

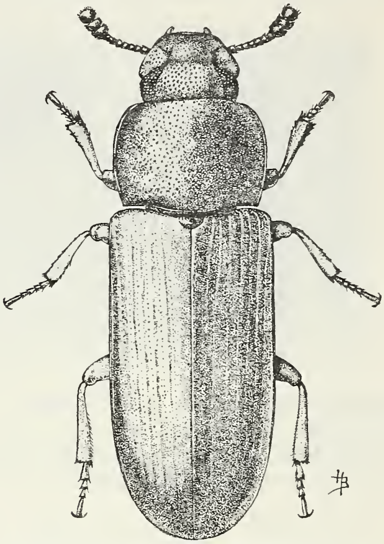

FIGURE 6.—The rust-red flour beetle, in common with the confused flour beetle, is one of the most troublesome insects found in flour mills.

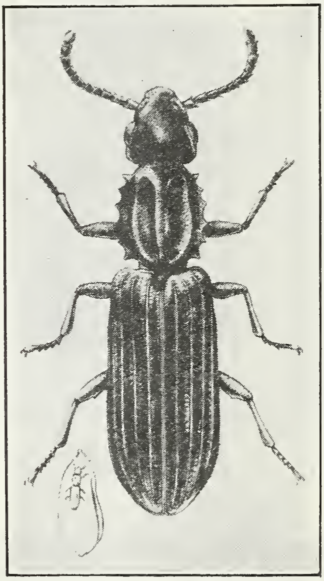

FIGURE 7.—The saw-toothed grain beetle is found in grain and in flour products that have been in the warehouse for some time.

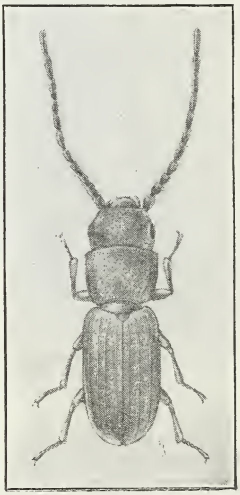

FIGURE 8.—The flat grain beetle, the smallest beetle found in stored grain, is often abundant in milling machinery. Damage caused by its feeding is slight.

depending on the tightness of the bin. To be effective the fumigating should be done only when the temperature of the grain or air is 70° F. or higher. *Smoking or the carrying of lighted lanterns in the building must be prohibited during the fumigation. If the building is wired for electricity, lights should not be turned on or off, since a spark of any kind may cause the carbon disulphide vapors to explode.*

Before placing newly threshed grain in bins on the farm, it is well to remove any old infested grain that may be left from the previous year and thoroughly clean out the bin.

CONTROL OF INFESTATIONS IN GRAIN ELEVATORS

When grain is brought to the elevators in cars, wagons, or trucks, it should be carefully examined for insect infestation and, if infested, should be stored in quarantine bins, where it can be fumigated. Infestations of the granary weevil (*Sitophilus granaria* L.) (fig. 9) and the lesser grain borer (*Rhizopertha dominica* Fab.) (fig. 10) usually originate in elevators. Before grain is stored, the bottoms and sides of the bins should be thoroughly cleaned; in the case of deep bins or silos, it would be more practical to fumigate the empty bins.

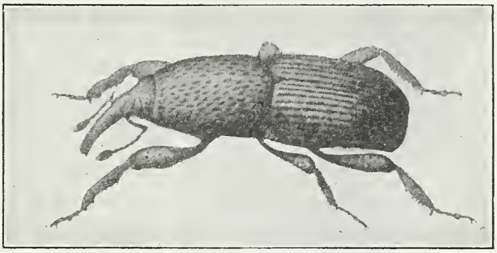

Figure 9.—The granary weevil is of frequent occurrence in stored grain.

SHIFTING AND CLEANING THE GRAIN

If grain is infested with the meal moth (*Pyralis farinalis* L.) or the Indian meal moth (*Plodia interpunctella* Hbn.), frequent shifting or transferring of the grain from one bin to another will destroy many of the insects, because the adults are unable to escape from deep down in the mass of grain. Passing the grain through a cleaning or fanning machine will remove large numbers of the insects feeding externally on the grain, but it will not remove the kernels infested with larvae of the Angoumois grain moth, the granary weevil, or the rice weevil, which pass their entire larval life within the kernels. The insects screened or removed by the cleaner must be killed or disposed of before they become distributed throughout the bins of the elevator.

COOLING THE GRAIN

Cooling the grain by transferring it from one bin to another during cold weather will frequently check insect activity. If, during this process, the grain is allowed to drop through the air or is passed through a dryer using cold blasts of air instead of hot, a much lower temperature can be obtained. If grain can be cooled to 40° F. or lower, insect activity will cease, and if this temperature is maintained for several months the insects will die.

HEATING THE GRAIN

Heating grain in a dryer to 130°–140° F. for 30 minutes will kill all insect life. This method of sterilization can be used to advantage by the miller, since the loss of weight by evaporation of moisture from the wheat will not be objectionable and the heat does not injure the milling qualities of the grain. This method, however, is not entirely satisfactory for grain that is to be kept in storage.

One type of heating unit that is in use in some parts of the United States for the treatment of wheat consists of an upright steel cylinder, which may be heated to a temperature of 125°–150° F. by either blowing in hot air or steam radiation at the base of the cylinder. The grain entering at the top of the cylinder flows down over aprons, which keep it spread and delay the time of reaching the bottom of the cylinder or the place where it passes out. The grain is only a few minutes in passing through the cylinder, the time depending on the temperature to which it is heated.

Another type of heater is a revolving horizontal cylinder or drum heated by steam either passing through pipes in the center of the cylinder or in a jacket surrounding the cylinder. The revolving cylinder is slanted just enough so that the grain entering at one end will soon move, as it is being agitated, to the other end, where it passes out.

Several types of heaters are used to warm the grain before tempering. Increased radiation and lengthened exposure, obtained by connecting two or more such units, could produce killing temperatures.

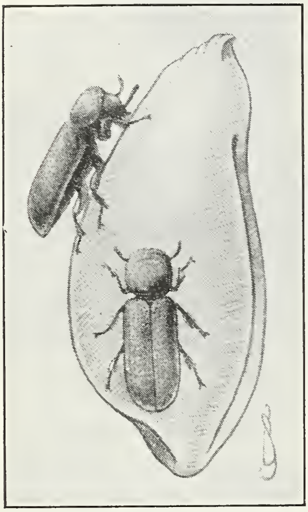

FIGURE 10.—The lesser grain borer has in recent years become common in stored grain in elevators.

FUMIGATING THE GRAIN

When it is impossible to cool the grain and undesirable to sterilize it with heat, a fumigant can be used to eliminate insect infestation. The fumigants available for use in grain elevators are calcium cyanide, ethylene oxide-solid carbon dioxide mixture, chloropicrin, and various mixtures of carbon disulphide, ethylene dichloride, or propylene dichloride with carbon tetrachloride.

CALCIUM CYANIDE

A crude granular calcium cyanide containing from 23 to 29 percent of available hydrocyanic acid is used to some extent for the fumigation of grain. On exposure to air the calcium cyanide combines with the atmospheric moisture to form hydrocyanic acid gas. The fumigant is applied by feeding it into the grain stream while the bin is being filled. Specially designed gravity-feed applicators, which fit on the drums of calcium cyanide in place of the tops, permit the fumigant to be run into the grain stream at any rate desired. To insure proper distribution, care should be taken that the fumigant is run directly into the grain stream as it enters the bin. Schenk [2] found that the best results are obtained with a dosage of 25 pounds per 1,000 bushels, although in commercial fumigation work 10 pounds per 1,000 bushels is ordinarily used. Grain should be kept in the bin for at least 3 days after fumigation.

Since hydrocyanic acid is deadly to human life, this fumigant should be handled with great care, preferably under the direction of a professional fumigator. The operator should keep away from the top of the bin while it is being filled, since the air displaced from the bin will contain some of the deadly gas. If possible, closed-top bins should be fitted with a vent to carry off the displaced air. Open-top bins should not be fumigated with this material. Bins that have contained grain fumigated with calcium cyanide should not be entered for some time after the grain has been removed, since dangerous concentrations of the gas may remain. In bins more than 40 feet in height, and where the operator would have to enter from the top to sweep out the bin, leaving the bottom slide open and running 25 to 50 bushels of wheat through the bin will eliminate the necessity of sweeping.

White corn and polished rice should not be fumigated with calcium cyanide, since grains having white surfaces are likely to become spotted with yellow from the treatment.

Tests made by Swanson and Working,[3] of the Kansas Agricultural Experiment Station, indicate that fumigation with calcium cyanide does not injure the feeding, milling, or baking qualities of wheat.

Hydrocyanic acid gas quickly evaporates from treated grain when it is aerated. If, however, grain arrives for inspection bearing an odor of hydrocyanic acid, it is liable to be condemned.

CHLOROPICRIN

Chloropicrin, one of the war gases, has recently been adapted for use as a grain fumigant. It is a heavy, volatile liquid with a rather high boiling point. On exposure to air it vaporizes slowly, forming a heavy gas that is very toxic to insects.

By means of a gravity-feed applicator the fumigant is applied directly into the stream of grain as it is run into the bin. A dosage of from 2 to 3 pounds per 1,000 bushels of grain gives satisfactory control.

Owing to its irritating effect on the eyes and mucous membranes, chloropicrin is rather disagreeable to handle. The baking and milling qualities of treated grain are temporarily impaired, but if the grain is well aerated the deleterious effects pass off. Chloropicrin clings rather tenaciously to grain; hence fumigated grain should be turned within a few days after treatment.

ETHYLENE OXIDE–SOLID CARBON DIOXIDE MIXTURE

A mixture of one part of ethylene oxide with nine parts by weight of solid carbon dioxide gives one of the most satisfactory fumigants for stored grain. It is noninflammable, safe to apply, and leaves no obnoxious odor or poisonous residue on the grain. The mixture is prepared outside the elevator by crushing the solid carbon dioxide and mixing it in pails with the ethylene oxide. It is applied by shoveling into the grain stream as the bin is being filled. A dosage of from 30 to 40 pounds of the mixture per 1,000 bushels of grain gives excellent results. The germination of fumigated grain is slightly affected, but otherwise there are no deleterious effects from the treatment with this mixture. It is not necessary to move the grain after fumigation.

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[2] SCHENK, G. CYANOGAS CALCIUM CYANIDE FOR THE CONTROL OF INSECTS INFESTING GRAIN IN STORAGE BINS. *In* Research in the Development of Cyanogas Calcium Cyanide, sec. 3, pp. 37–69. New York. 1926.

[3] SWANSON, C. O., and WORKING, E. B. HOW FUMIGATION AFFECTS WHEAT. Millers' Rev. and Dixie Miller, 90 (2): 28–30. 1926.

MIXTURES OF CARBON DISULPHIDE AND ETHYLENE DICHLORIDE WITH CARBON TETRACHLORIDE

Although carbon disulphide and ethylene dichloride are also effective fumigants, because they are inflammable it is not safe to use either of them alone. In fact, the use of carbon disulphide is prohibited at the large country elevators and generally at railroad terminals. Carbon tetrachloride, on the other hand, when used alone is not sufficiently toxic to be useful as a grain fumigant, but when it is mixed with one of these inflammable materials a satisfactory fumigant with a relatively low fire hazard is obtained.

Mixtures containing carbon disulphide are effective in proportion to the carbon disulphide content. Under ordinary conditions a dosage of from 1½ to 2 gallons of such mixtures per 1,000 bushels of grain will give a commercial kill. A mixture of three parts of ethylene dichloride and one part of carbon tetrachloride (by volume) is a good general fumigant when used at temperatures above 70° F. It is about one-fifth as toxic as carbon disulphide against the rice weevil, and should be used accordingly. Both these mixtures should be applied as the grain is run into the bin, by pouring or dripping into the grain stream. There is no deleterious effect on the grain if a good grade of material is used. The ethylene dichloride mixture has a sweetish, chloroformlike odor, which is rather persistent, but can be eliminated by aeration.

No elevator man should attempt to mix his own fumigant, and only reliable brands that are approved by an insurance underwriter should be used.

Mixtures of propylene dichloride and carbon tetrachloride have been tested as grain fumigants, but they have not given satisfactory results in elevators.

Sulphur dioxide and other chemicals are sometimes used in combination with carbon tetrachloride to reduce the fire hazard of carbon disulphide.

INSECT PESTS IN THE FLOUR MILL

INSECTS FOUND IN FLOUR MILLS

Many of the insects that attack stored grain are also found in flour mills, but only a few of them can be considered major pests. The confused flour beetle (fig. 5), the rust-red flour beetle (fig. 6), and the Mediterranean flour moth (*Ephestia kuehniella* Zell.) (fig. 11) are the most serious pests of the flour mills in the United States. Other pests causing considerable trouble in flour mills are the cadelle, the Indian meal moth (fig. 12), the black carpet beetle (*Attagenus piceus* Oliv.) (fig. 13), the saw-toothed grain beetle, and the flat grain beetle.

FLOUR BEETLES

The confused flour beetle (fig. 5) and the rust-red flour beetle (fig. 6) are the most difficult to control of the insects found in flour mills. They get into all parts of the milling machinery and are the insects most commonly found in flour after it leaves the mill. They are reddish-brown beetles about one-eighth of an inch in length, and the two species are almost identical in appearance. The adults are long-lived, some of them surviving for nearly 2 years. The females lay on an average 400 to 500 eggs each, dropping them here and there in the flour or foodstuff. The developmental period from egg to adult in warm weather and with favorable food may be as short as 4 weeks, but cold weather or unfavorable food conditions will prolong this period considerably.

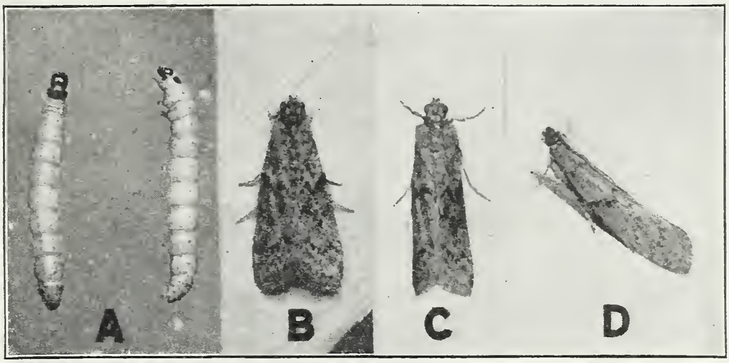

FIGURE 11.—The Mediterranean flour moth: *A*, Larvae; *B*, *C*, and *D*, adult in various positions.

THE MEDITERRANEAN FLOUR MOTH

The Mediterranean flour moth (fig. 11) was formerly the most troublesome pest of flour mills. The larvae spin silken threads wherever they go, webbing and matting the flour particles together until the machinery becomes so clogged that the operation of the mill is seriously impeded (fig. 14). This insect is no longer a serious pest in the larger mills that have an annual fumigation program, but in mills that are not fumigated regularly it is still a major problem.

The adult moth has a wing spread of about 1 inch; its hind wings are a dirty white, and the fore wings are a pale gray, transversed with wavy black lines. The female moths lay their eggs in accumulations of flour or other milled products. In a few days these eggs hatch into larvae, or caterpillars, that when fully grown are about half an inch long. They are whitish or pinkish, with a few small black spots on the body. In warm weather the developmental period from the egg to the adult moth is about 8 or 9 weeks.

THE INDIAN MEAL MOTH

The Indian meal moth (fig. 12) is seldom a pest of milling machinery. It prefers the coarser grades of flour and milled products and is the insect most commonly found in packages of whole-wheat and graham flour and corn meal. Like the Mediterranean flour moth, its larvae spin silken threads, and in bins of grain that have been neglected the surface of the grain may be completely matted together and covered with a thick web of silk. Infestations of the Indian meal moth are occasionally found in the middlings purifiers.

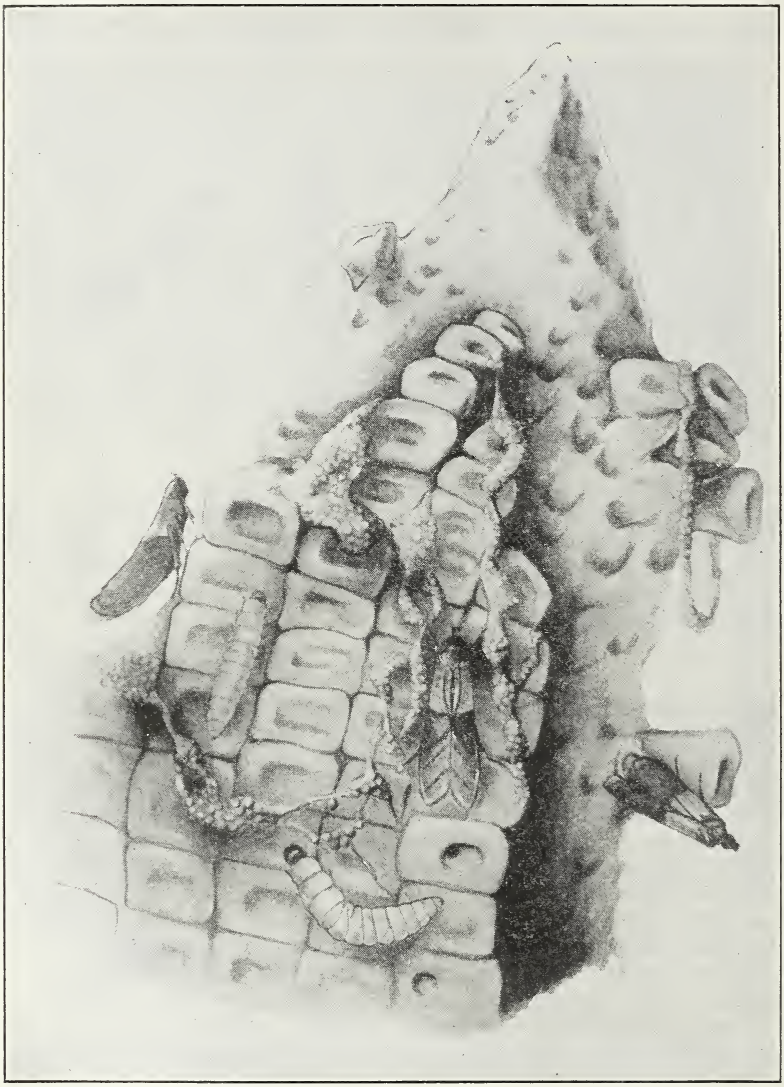

FIGURE 12.—The Indian meal moth is sometimes troublesome in flour mills.

The adult moth is slightly smaller than the Mediterranean flour moth and is easily distinguished from it by the peculiar markings of its fore wings. These are grayish white on the inner third, with a broad coppery-brown band on the outer two-thirds. The females lay on an average about 200 eggs, placing them singly or in groups on the foodstuff. The caterpillars that hatch from the eggs are dirty white in color, with sometimes a greenish or pinkish tint. When fully grown they are about half an inch long. The developmental period from egg to adult may be passed in 4 weeks in summer.

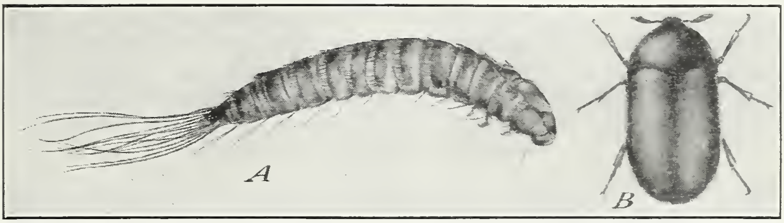

FIGURE 13.—The black carpet beetle occasionally causes serious damage to the silks of machines not in use: *A*, Larval skin showing the typical shape of the larva and the long tuft of bristles at the end of the body; *B*, adult beetle.

THE CADELLE

The cadelle (figs. 3 and 4) is sometimes called the "bolting cloth beetle", because of its habit of cutting the silk cloths in bolting reels and redressing machines. The beetle does not feed upon the silk, but upon grain, flour, and milled products, as does its larva. Both larvae and beetles are found in accumulations in the bottom of elevator boots and the flour conveyors, and they are common pests in bags of flour in the warehouse. During blending operations the larvae are sometimes bolted out by the thousands. The senior author recalls one instance where two 140-pound bags of a straight-grade flour were found to contain 1,460 and 1,000 worms, respectively, just previous to shipping.

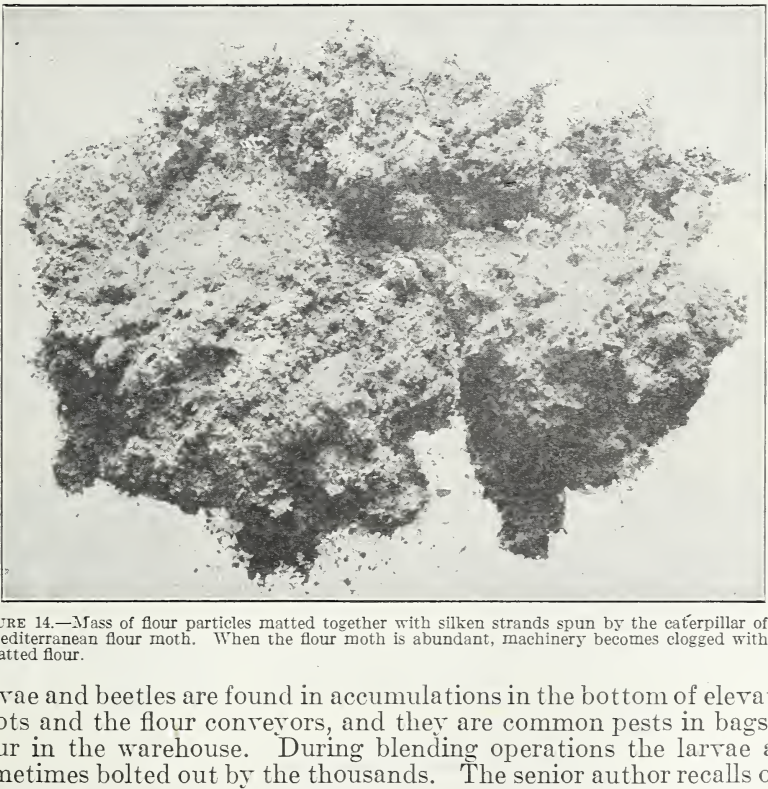

FIGURE 14.—Mass of flour particles matted together with silken strands spun by the caterpillar of the Mediterranean flour moth. When the flour moth is abundant, machinery becomes clogged with the matted flour.

The adult cadelle is an elongate, oblong, flattened, black beetle about one-third of an inch long. The adults live for from 1 to 2 years, and the females lay about 1,000 eggs each. The larvae are about three-fourths of an inch long when fully grown, fleshy, and have abdomens terminating in two dark horny points. They are white, with head, thoracic shield, and the two horny points at the end of the body black. Under favorable conditions the period from egg to adult can be passed in about 10 weeks, although it is usually much longer. The larvae burrow into woodwork to pupate, and it is not uncommon to find beams and boards about a mill honeycombed with their burrows.

THE BLACK CARPET BEETLE

The black carpet beetle (fig. 13) belongs to a group of beetles that are scavengers. The larva, which is the only stage that is injurious, is nearly omnivorous, feeding upon fabrics, milled products, and all types of dried animal matter. It is commonly found in accumulations of waste grain products and in cracks in floors or woodwork, where flour and lint collect. When bolting reels and redressing machines are allowed to stand idle, considerable damage is sometimes caused to the silk cloths by the feeding of the larvae (fig. 15).

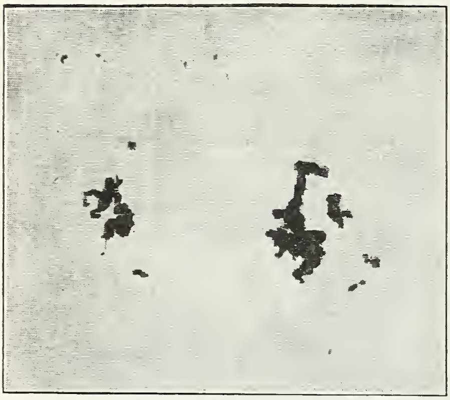

FIGURE 15.—Damage to silk bolting cloth caused by larvae of the black carpet beetle.

The adult is a small black beetle between two- and three-sixteenths of an inch long. It is frequently seen in mills in the spring crawling on the windows, over the bags of flour and feed, and on the floors. The beetles lay their eggs in any convenient supply of foodstuffs, and these soon hatch into reddish or golden-brown worms, clothed with short hairs and bearing a tuft of long hairs at the end of the body. There is only one generation a year. The larva develops slowly throughout the year and transforms to an adult beetle in the spring.

THE SAW-TOOTHED GRAIN BEETLE

The slender, flat, brown saw-toothed grain beetle (fig. 7) gains its name from the peculiar structure of its thorax, which bears six saw-toothed projections on each side. It is about one-tenth of an inch long. It is a cosmopolitan pest of stored grain and grain products of all kinds. Although often found in flour mills, it is usually more troublesome in warehouses.

The adult beetles may live for more than 3 years, although the average length of life is from 6 to 10 months. The females lay from 45 to 285 eggs each. The developmental period in summer may be passed in as few as 22 days.

THE FLAT GRAIN BEETLE

The flat grain beetle (fig. 8), a small, flattened, reddish-brown beetle, is the smallest beetle commonly found in the flour mill, being only about one-sixteenth of an inch long. It does little active damage by its feeding, but its presence is undesirable. After a fumigation the dead bodies of this species are often seen in numbers on the floor near elevator boots or in the sifters. The flat grain beetle feeds in grain and grain products of all kinds, but the details of its life history are not well known.

COCKROACHES

Cockroaches are very common in the basements of many flour mills. After a fumigation they can sometimes be swept up by the bucketful. The oriental cockroach (*Blatta orientalis* L.) (fig. 16, *A*, *B*) and the American cockroach (*Periplaneta americana* L.) (fig. 16, *C*) are the species most commonly found.

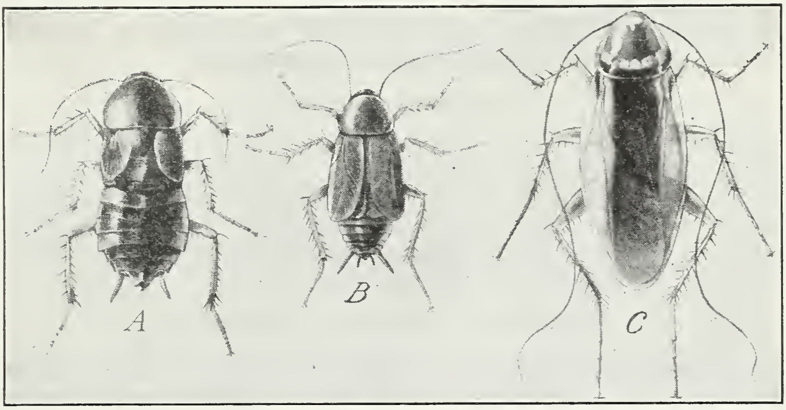

FIGURE 16.—These cockroaches are common inhabitants of the basements of flour mills: *A*, Female, and *B*, male, of the oriental cockroach; *C*, the American cockroach.

AVENUES OF INFESTATION IN FLOUR MILLS

To control the insects that are troublesome in flour mills, it is essential to know the avenues by which they gain entrance. The most significant of these, as disclosed by investigations of State and Federal workers, are, in order of importance, the grain stream, returned infested products, stock used for blending purposes, used bags, and infested used machinery.

THE GRAIN STREAM

Grain coming from the elevator to the mill is frequently infested with several species of insects, some of which are of major importance to the miller. In many mills the cleaning machinery is placed close to the milling units, and in such cases insects removed from the grain stream in the cleaning process have easy access to the milling machinery. To remedy this situation in the modern mill the cleaning machinery is segregated in a smut room at one end of the mill. Screenings and grain dust should be immediately disposed of or treated with fumigants or heat.

All milling mixes contain some insects, but the number is generally so small that fumigation of the grain is not practical. Investigations are now in progress to develop a practical and efficient method for treating grain as it enters the mill and thus to close the most important avenue of infestation.

Conveyors carrying grain from the storage bins to cleaning machinery should never pass through the flour warehouse, since this gives insects ample opportunity to crawl from the conveyors and drop onto stored flour.

It is possible for insects to pass through the entire system of rolls. Adults of the confused flour beetle have been observed to pass unharmed through the first three breaks, and partly grown larvae are able to survive passage through the first three middlings rolls. Eggs of this species are so small that many of them are able to survive passage through the low-grade rolls, and these surviving individuals start infestations which soon reach serious proportions in all streams of the milling unit.

Supplementary control measures (p. 30) can, however, be used to hold this infestation in mill streams to a minimum.

RETURNED PRODUCTS

Returned products are always a problem to the miller, since they constitute a serious source of infestation. The returned stock, which frequently is infested, is usually fed in one of the many "blends" or "mixes" which modern milling demands, and unless such flour is sterilized by heating or fumigation, the machinery used in handling such stock immediately becomes infested.

STOCK USED FOR BLENDING PURPOSES

The demand for blended flour by large baking concerns necessitates the use of large quantities of clear and low-grade flours, which are generally obtained from small mills. Usually these flours have accumulated over a period of time, and frequently they are infested. When such stocks are blended during the milling operation, not only machinery but the resulting flours also become infested. Blending reels usually are equipped with bolting cloth not fine enough to prevent passage of eggs and the smaller larval stages.

Large milling companies that follow the practice of transferring certain stocks from one mill to another for blending purposes frequently find infestations in mills receiving such stock. A coordinated insect-control program will eliminate much of this trouble. Where blending operations are conducted, it is essential that supplementary control measures (p. 30) be followed to prevent the building up of serious infestations in the machinery involved.

USED BAGS

It is well known that returned bags are usually infested with insects of various species. The millers who use such bags should not bring them into the mill or adjoining room until they have been treated by fumigation or heat. Cleaning of the bags by air suction reduces the danger of infestation but does not eliminate it, for many eggs and even small larvae clinging tightly to the fibers of the sacks are not removed. Moreover, air-cleaning machinery is frequently located either in the mill proper or in adjoining rooms, where bales of bags may remain from several hours to several days before reaching the cleaner, and during this period many of the insects may have been shaken or brushed from the bale or have crawled to other parts of the building.

OTHER SOURCES OF INFESTATION

Used machinery is occasionally purchased from mills that are being dismantled. Such machinery is invariably infested with insects and should be fumigated. If a fumigatorium is available, any machinery that can be placed conveniently in the vault should be fumigated before loading. When no vault is available, the larger machinery, or all machinery, should be fumigated in the railway car before shipping. Buyers or users of such machinery should again inspect the car before unloading, and if there are signs of infestation, especially by the Mediterranean flour moth, the machinery should again be fumigated before it is unloaded. The procedure given under Railway-Car Fumigation (p. 33) should be followed.

CONTROL BY SANITATION

To hold insect infestation in the mill at a minimum, it is important to keep the entire plant scrupulously clean. Flour and meal should not be allowed to accumulate on the floors, in the corners, under machinery, or in other places where it may find lodgment. Milling equipment should be designed to leave a minimum space for such accumulations. All machinery should be placed high enough to allow thorough cleaning and brushing beneath it. As far as practicable, the bottoms of all conveyors should be metal and should be rounded in such a manner as to give the least dead space. Much dead space at the end of the conveyor can be eliminated by fitting the outlet spout to the bottom of the conveyor instead of to the side.

It has been noted that where oil from the bearings had spilled into dead ends of conveyors or other parts of the machinery, little or no insect life is found. Since a mixture of about 10 parts of flour, or fine meal, to 1 part of machine oil (by volume) will not sustain mill-insect life, breeding places about the machinery which cannot be otherwise eliminated may be filled with such or a similar material. In one mill dead spaces in the bottoms of bolters and bran dusters, in the ends of purifiers and reel conveyors, and in various other places were filled with liquid asbestos mixture, which upon solidifying eliminated this space. Each miller should study his own problem and eliminate as much dead space about the machinery as possible.

Buildings should be so constructed as to avoid damp, dark places. All walls and ceilings should be smooth to eliminate hiding and breeding places for insects, and they should be either painted or whitewashed. Floors and walls should be joined in such a way that accumulations along the edges and in the corners can be easily swept out. All basement floors should be of concrete. To avoid infestation in the dark corners and other places in the basement, a liberal quantity of air-slaked lime should be used. This lime will not only act as a repellent for the insects, but will also help destroy objectionable odors.

About every 2 weeks during the warm months, all accumulations of flour and meal in the elevator boots, conveyors, bolters, purifiers, reels, etc., should be cleaned out and removed from the mill. Before doing this it is well to go over the elevator legs and spouts with a rubber mallet or spout maul to jar loose the insects and infested accumulations. Such material can be heated or fumigated in an airtight vault and later reconditioned, but if no vault is available it should be burned.

Sacks or bags should not be stored in the packing room or in any part of the mill where flour or meal can collect on them and thus afford breeding places for insects. The sack room should be separate or tightly partitioned off from any part of the mill.

Small lots of flour are sometimes left for several days near machinery that is known to be heavily infested. These lots of flour invariably become infested from insects that leave their hiding places and crawl out onto the bags, especially where the elevator boots end on the load-out or the packing floor.

FUMIGATION

GENERAL PROCEDURE AND PRECAUTIONS

At times all mills become so heavily infested that simple remedial measures are insufficient and more radical treatments, such as fumigation or heat treatment, are necessary.

Success in the fumigation of any mill depends on the proper planning and execution of the work, the careful preparation of the building, and the correct choice of the fumigant, a lethal dosage, and proper time of its application.

Since all gases are more active and efficient at high temperatures, it is desirable to maintain a high temperature in the building during the fumigation. Insects are not very active below 60° F. and become more or less dormant at 50° or below. In the dormant state they are extremly difficult to kill with fumigating gases. For best results a temperature of at least 75°, and preferably somewhat higher, should be maintained throughout the fumigation.

If possible, the fumigation should be conducted when there is little or no wind, as the greater its velocity during a fumigation the poorer are the results. Apparently the proper distribution of the gas is prevented by a strong wind, air pockets being formed which cannot be penetrated by the gas. A dead air space serves as a protection to the insects.

The length of exposure may range from 12 to 24 hours, depending on the construction of the building and the degree of penetration necessary. Loosely constructed buildings will not hold the gas in killing concentrations for more than 12 hours. Longer exposures are more useful in tight buildings where deep penetration is desired.

The fumigant should be applied in such a way that a maximum concentration is obtained as quickly as possible. If the concentration is slow in building up, the natural leakage from a building is often great enough to prevent a killing concentration from ever being attained in all parts of the structure.

Unless the fumigant is applied from outside the mill, the fumigating crew should be supplied with gas masks having canisters adapted for the gas that is to be used. Each man should be familiar with the entire plan of procedure as well as with his own particular job. One man should be delegated to watch the others, and give aid in case anyone gets into trouble. Help given at the right time will prevent fatal accidents.

Before the fumigation is started, the building should be thoroughly searched to make sure that no workers or visitors are inside. While the building is under fumigation all entrances should be kept locked and usually guarded by watchmen. Placards warning people to keep out should be tacked on all doors. If the mill is located in a congested area and is separated from adjacent buildings only by a party wall, the adjoining buildings should be vacated during the fumigation.

After the fumigation the buildings should be thoroughly aired by opening windows, ventilators, and doors. If possible, arrangements should be made to open these from the outside. If this is not feasible, the buildings can be entered by workmen wearing gas masks. To avoid accidents, two men should always work together when ventilating a building. The watchmen should be instructed to prevent anyone from entering the building while it is being ventilated.

In many cities it is necessary to obtain a permit from the local health department before conducting a fumigation. In all cases the police and fire departments should be notified.

PREPARATION OF THE MILL

SEALING

The effectiveness of a fumigation depends largely on the tightness of the building. Instead of each floor being fumigated separately, the entire mill should be considered as one unit, since inspections and observations after fumigation have shown that many insects are able to survive in the sacking or other material used to plug openings running from floor to floor. All windows should be tightly wedged or sealed, and any broken panes should be replaced. Loosely fitting window sashes should be sealed with paste and paper, or "puttied up" with flour and oil mixed to the consistency of putty. For stripping window frames that are only slightly loose, several types of material can be used; rolls of gummed paper, strips of newspaper smeared with grease or pasted with flour paste, or rolls of unsterilized adhesive tape are suitable. Sometimes it is impossible to tighten a window by the ordinary method of sealing or stripping and it is necessary to seal the entire aperture. For this purpose car-lining paper can be used.

Small doors leading to the exterior of the building can be tightened with any of the materials used for the windows. Large sliding metal or wooden doors that fit imperfectly can be caulked up with the flour-and-oil mixture or with a paste composed of 4 parts of asbestos to 1 part of calcium chloride mixed with a little water. Both these mixtures form an effective seal, yet can be easily removed after fumigation.

For sealing ventilators three thicknesses of heavy paper, covered with sacking or canvas, well pasted and tied, are often used when these are sealed from the roof. Some ventilators are more easily sealed from the settling chamber below the ventilator. Wherever possible, it is desirable to remove the mushroom-shaped cap of the ventilator and replace it with a metal cap which fits the ventilator trunk snugly.

CLEANING OPERATIONS

Before Stopping Mill

1. Shut off feed (wheat) at mixing bin.
2. Continue running all machinery until material is emptied from spouts, elevators, conveyors, rolls, sifters, reels, purifiers, feed dusters, suction trunking, and dust collectors.
3. Remove elevator-boot slides and station men along the boots to keep stock pulled out where belt cups will not carry it up in its natural course.
4. Meanwhile hammer elevator legs, machinery, frames, tubular dust collectors, and spouts with a rubber mallet or other device which will not bruise or injure the equipment.

After Stopping Mill

1. Open all machines, conveyor boxes, and flour bins.
2. Remove covers of all conveyors, making certain that all dead-end spaces are readily accessible.
3. Thoroughly clean all conveyors, including dead-end spaces.
4. Clean out accumulations from bottom section of the bran duster.
5. Clean all elevator belting that may be webbed; drag spouts of same.
6. Remove adjustable feed gage above grinding rolls and clean out accumulations above rolls and feeders.
7. Examine tubular dust collectors and clean out all accumulations.
8. Clean out suction trunks, conveyors, and dust-collector systems.
9. Open dust collector, back drafts, main trunks, and hand openings.
10. Loosen all sifter doors to permit entrance of gas during fumigation; remove sieves and stack same on the floor.
11. Leave every machine open; also all hand openings to spouts, elevator legs, etc.
12. Remove and burn all infested materials accumulated in cleaning the mill
13. All infested lots of flour and other milled products should be removed (or reconditioned) before cleaning the mill. These products should not be returned.
14. If the foregoing procedure is followed, no accumulation of more than 1 inch in depth will be present in the mill.
15. Special attention should be given to the cleaning of the dead spouts and dead spaces in corners of spouts and machines.
16. Remove all bags or other materials used to plug spouts.

FUMIGATION WITH HYDROCYANIC ACID GAS

For the fumigation of mills there is no more efficient gas than hydrocyanic acid. It is relatively inexpensive, kills with great rapidity and, although fatal to human life, can be handled with reasonable safety by experienced men. It can be used in all types of mills and is harmless to flour-mill products, as used in ordinary mill fumigation.

Hydrocyanic acid gas is commonly produced in four ways. They are listed in order of importance as follows:

(1) The liquid method, which consists in pumping liquid hydrocyanic acid into the building.

(2) The barrel or pot method, which consists in generating hydrocyanic acid gas in a barrel or other container.

(3) The calcium cyanide method, which consists in spreading on the floor of the building calcium cyanide, which combines with moisture in the air to form hydrocyanic acid gas.

(4) The discoid method, which consists in spreading on the floor discoids of an absorbent material saturated with liquid hydrocyanic acid.

THE LIQUID METHOD

Liquid hydrocyanic acid (96–98 percent HCN) is a volatile, colorless liquid boiling at 79° F. On exposure to air it changes to a gas that is lighter than air. It is marketed in cylinders containing 30 or 75 pounds. If handled properly, it is an almost ideal fumigant for mills.

After the mill has been prepared for fumigation, the gas is applied entirely from the outside. The cylinders containing the liquid hydrocyanic acid are lined up near the building, and the fumigant is forced in by compressed air (fig. 17). To obtain a proper distribution of gas within the building, metal piping equipped with spray nozzles is used.

Piping the mill.—In mills fumigated by the liquid method a permanent system of piping is installed. Either brass or copper piping is recommended. Iron piping is less expensive, but because of its tendency to rust and cause clogging of the spray nozzles it is less desirable. A flexible copper tubing three-eighths of an inch in diameter costs about 6 cents a foot. Since it can be readily bent, elbow fittings are unnecessary, and compression couplings can be used, except at the main inlet, where the cylinders are connected. Most mills can be piped with copper tubing at a cost of 10 to 13 cents per 1,000 cubic feet of space, including cost of material and installation. Brass tubing costs about two and one-half times as much as copper.

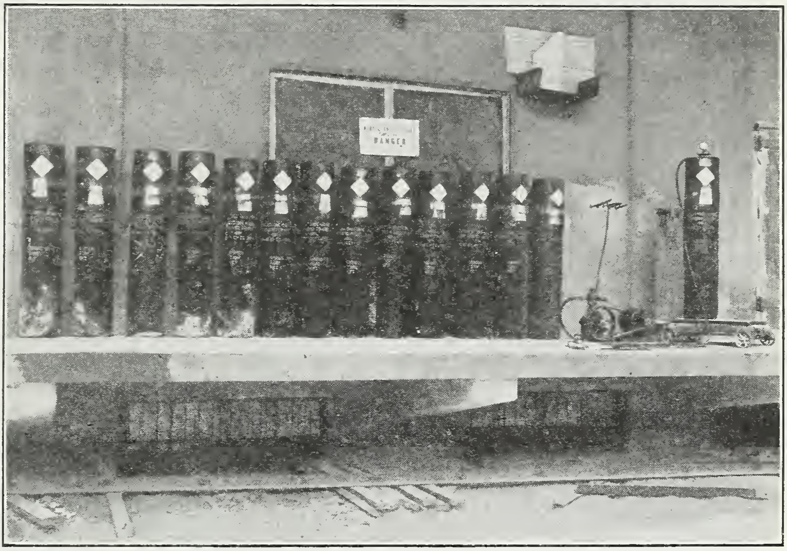

FIGURE 17.—Liquid hydrocyanic acid being pumped into a flour mill undergoing fumigation.

In large mills of several floors, where numerous branch lines are used, each floor should be provided with a separate riser. At least one spray nozzle should be provided for every 20,000 cubic feet of space, and it is generally advantageous to use more than this. The piping system should be so arranged that the pressure of the gas will be approximately the same at all nozzles, thus insuring an even distribution of the gas. Each riser is connected with a special inlet pipe leading through the outside wall of the building.

Piping plans are usually designed by an employee of the fumigating company after he has made a survey of the building. Should blueprints of the mill or rough sketches and measurements be forwarded for making piping plans, special attention should be given to offsets and whole or part partitions. Any other special condition, such as heavily infested machinery, rows of packing machines, or other places of heavy infestation, should be noted in order that an extra spray nozzle may be added at this point if it is thought advisable. There should be not more than 10 spray nozzles to each riser. Where grain or flour bins are piped, a separate riser for these bins should be used.

Reinforced rubber hose is used to connect the cylinders to the piping system. This hose must always be kept in good condition, since there is always some danger of weakened hose bursting under pressure and showering the operator with the deadly fluid.

Before the material is applied, care should be taken that all connections outside the building are tight. Should a leak develop from a loose connection where the hose from the cylinder is attached to the piping, such connection can be tightened with reasonable safety if the operator wears a gas mask and is careful that the liquid does not spray his clothing. If the pipe wrench is operated with the handle above the connection instead of below it, the material will not run down the handle onto the arms and clothing. If in doubt whether the spray has reached the clothing, or if the liquid has run down the arms and possibly onto one's shirt or coat, the shirt or coat should be removed and the hands and arms washed *before the mask is removed.*

Applying the gas.—Each cylinder of liquid hydrocyanic acid is supplied with an inlet and an outlet valve. The outlet valve is attached to a steel tube connected with the bottom of the cylinder. The inlet valve leads directly into the top of the cylinder, and through it air is pumped, by means of a compressor, until a pressure of about 100 pounds is obtained. The outlet valve, which in the meantime has been connected with the inlet pipe to the building, is then opened and the liquid is forced into the building. The pressure must be maintained until all the liquid has been blown through the pipes into the building. The pipe lines are then blown clear and the inlet tubes capped.

Recent observations indicate that application of the gas directly into the machinery has advantages over the system described above. A higher concentration of gas in the milling machinery is obtained, thus insuring better penetration, and the labor of opening up the machinery is eliminated, with a consequent material decrease in cost. In this method the spray nozzles are placed directly in the milling machinery instead of having them discharge into the building space.

Removal of spray nozzles.—After the fumigation and after the building has been well ventilated, the spray nozzles should be removed for storage and the pipes capped. While removing spray nozzles the operator should take care to prevent any liquid, which sometimes remains in the pipe, from dropping onto the face or other parts of the body. He should never stand directly under the nozzle while removing it. Should any liquid hydrocyanic acid be lodged behind the nozzle, a decided cooling effect will be noticed while the nozzle is being unscrewed. It is best to use a gas mask in this work.

Special pressure nozzles are now on the market which do not clog and need not be removed.

Dosage.—The dosage will depend on the construction of the mill and the degree of penetration desired. In general, 8 ounces of liquid hydrocyanic acid for each 1,000 cubic feet of space will give excellent results. Ordinarily the gas is evenly distributed on all floors, but a larger quantity should be used on floors that contain more machinery than others.

THE BARREL OR POT METHOD

The barrel or pot method of generating hydrocyanic acid is so called because the chemicals used in the process are placed together in a barrel or similar container. The miller who does his own fumigating generally uses this method, and it gives good results if properly applied. It is cheaper than other methods, but more laborious, and the hot gas is likely to escape from the building faster than the cold gas produced by other methods (figs. 18 and 19).

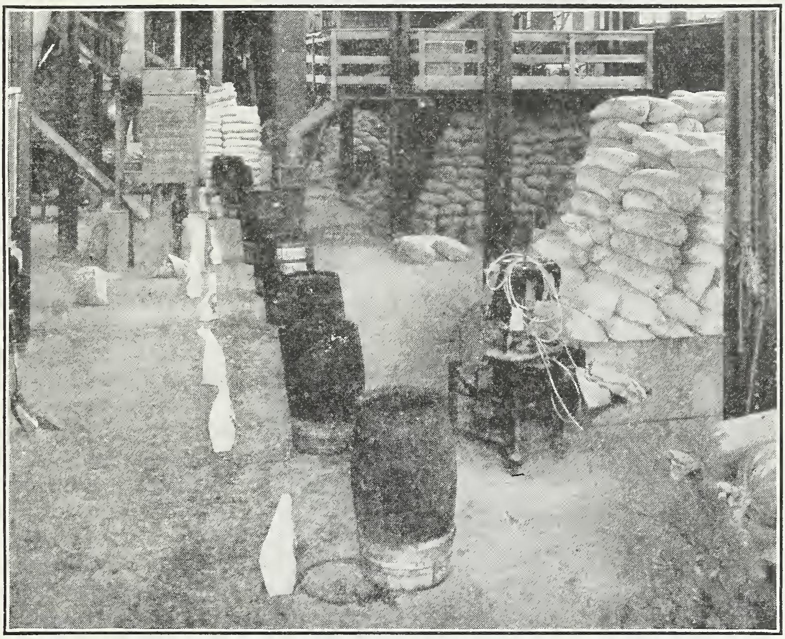

FIGURE 18.—Fumigation of a mill with hydrocyanic acid gas by the barrel method.

Chemicals required.—Sodium cyanide (96 to 98 percent, containing 54 percent of available HCN), a commercial grade of sulphuric acid (66° B.), and water are the only materials required. For best results they should be mixed according to the following formula:

Sodium cyanide	pound	1
Sulphuric acid	pints	1½
Water	do	2

Sodium cyanide is a white crystalline substance, which for fumigation purposes is prepared in egg-shaped lumps weighing approximately one-half to 1 ounce each. It is a violent stomach poison, and in addition can cause serious poisoning by being absorbed through open cuts. For this reason it is best handled with a scoop or shovel or with gloved hands.

Sulphuric acid is a heavy, colorless liquid when pure, but the commercial acid used in large-scale fumigation work is slightly discolored, or murky, owing to impurities. It is highly corrosive and will cause injury if it spatters on the clothing or body of the operator or upon the floor. It can be purchased in 11-gallon carboys. When large quantities of acid are required, a tilting frame will be found convenient in pouring the acid from the carboys.

Proper order of placing chemicals in generator.—To generate hydrocyanic acid gas by this method, the operator should first pour the water into the generator and then add the acid. If the procedure is reversed, the reaction is so violent that the operator may be dangerously burned by the spattering of the acid-water mixture.

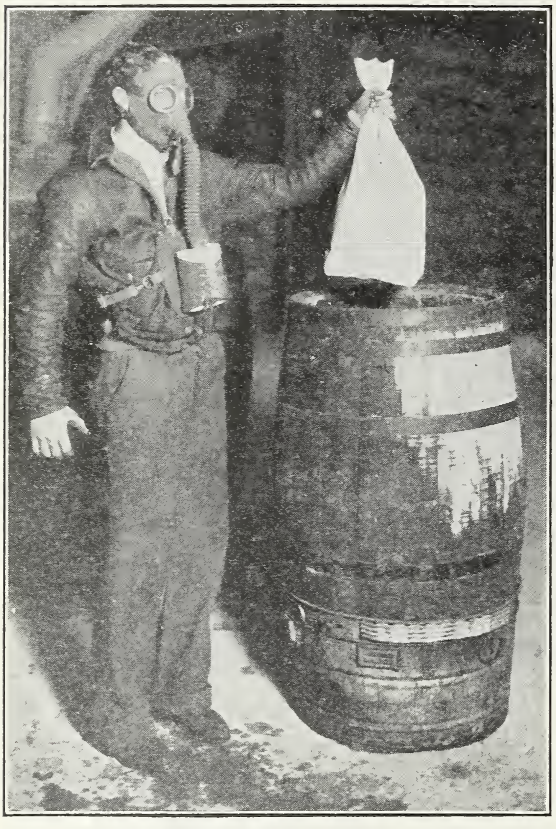

FIGURE 19.—Man wearing gas mask about to lower a bag of sodium cyanide into a barrel containing sulphuric acid and water.

The addition of the sodium cyanide to the mixture of water and acid causes an immediate chemical reaction in which hydrocyanic acid gas is given off. The pure gas is colorless, but when mixed with steam produced by the chemical reaction it has the appearance of a light bluish smoke. It has an odor resembling that of peach kernels.

The dosage.—The dosage is computed on the basis of the quantity of sodium cyanide required. For general mill fumigation 1 pound of sodium cyanide will produce enough gas to fumigate 1,000 cubic feet of space, if the building is of reasonably tight construction.

The generator.—For large-scale fumigation a watertight 50-gallon barrel is the most suitable generator to use. Each barrel will hold a maximum charge of 30 pounds of sodium cyanide, or enough to fumigate 30,000 cubic feet of space. When it is necessary to fumigate small rooms of a few thousand cubic feet as separate units, earthenware or stone jars of appropriate size can be used. A 4-gallon jar will hold a charge of 3 pounds of sodium cyanide.

Each barrel generator should be set in a galvanized-iron washtub in which has previously been placed a pailful of water containing several handfuls of washing soda. This precaution provides for catching and neutralizing small quantities of the acid-water mixture that may leak out of the barrel.

If three or four bricks are placed in the bottom of the washtubs for the barrels to rest on, they will not become stuck in the tubs.

Placing the generators.—If possible, the generators should be spaced evenly over the floors to obtain an even distribution of the gas. If necessary, however, the generators for one floor can be grouped together near the exit (fig. 18). The gas will eventually be dispersed to all parts of the enclosed space, though not so rapidly as when the generators are scattered evenly over the floor.

Generating the gas.—After the mill has been prepared for the fumigation and all the generators have been placed in their proper positions, the water and acid are measured out and distributed. The acid can be poured from the carboys into heavy galvanized-iron buckets, which will resist the action of the acid long enough for it to be distributed without accident. If jars are used for generators, the acid must be poured into the water slowly, lest the heat developed by the chemical reaction between the water and acid cause the jars to break.

After the foreman of the fumigating crew has determined that none of the barrels leak, the sodium cyanide, which has been weighed in the proper quantities and placed in bags, should be placed beside the generators.

When all the precautionary measures have been taken, and as soon as possible after the water and acid have been mixed, the fumigating crew should proceed to the top floor of the building and, starting with the generator farthest from the exit, lower the bags gently into the generators, proceeding downward from floor to floor as rapidly as possible. The foreman should not take part in the lowering of the cyanide, but should watch the crew to see that none of the generators are skipped, and that none of the men get into trouble.

Since the gas is generated as soon as the acid-water mixture comes in contact with the sodium cyanide, the operators engaged in dropping the cyanide should wear gas masks (fig. 19).

Emptying the generators.—When the fumigation is finished and the building has been thoroughly ventilated, the residue must be emptied from the generators. Sometimes the chemical reaction is incomplete, because some of the sodium cyanide has not come in contact with the acid-water mixture. When the generator is moved, the contents are shaken up and small quantities of gas may be given off. For this reason the operator should breathe as little as possible while handling the barrels and should not hold his head over the barrel.

The residue, which is poisonous, can be disposed of by pouring it into a hole in the ground and covering it with soil. When disposing of the residual material after fumigation, the operator should never bend over the hole, but should stand to windward and lean away from the hole as much as possible.

CALCIUM CYANIDE METHOD

Although not extensively used in mill fumigation, calcium cyanide in dust form is occasionally used to generate hydrocyanic acid gas. Upon exposure to the air the powder absorbs moisture and a chemical reaction takes place by which hydrocyanic acid gas is given off. Two forms of calcium cyanide are on the market, one containing 22 to 28 percent of available hydrocyanic acid gas and the other 51 to 52 percent.

The required number of cans of calcium cyanide are distributed about the building. They are then opened and the contents scattered over the floor in a layer not more than half an inch thick. It is desirable to scatter the 51 to 52 percent material on strips of paper previously laid on the floor to facilitate removal of residue after fumigation. The other form is more granular and can be easily swept up.

The fumigator should begin distributing the dust on the top floor at the point farthest from the exit, so that he will be working away from the gas and toward the exit to the floor below. Inasmuch as the gas is given off as soon as the dust is exposed to the air, the fumigators should wear gas masks.

The residue should be disposed of outside the building as soon as possible after the fumigation, since some hydrocyanic acid gas is likely to be retained. After all the hydrocyanic acid gas has been given off, the residue is nonpoisonous.

One pound of the 51 to 52 percent material per 1,000 cubic feet of space should be used, or 2 pounds of the 22 to 28 percent material.

THE DISCOID METHOD

Liquid hydrocyanic acid gas adsorbed in an inert material is useful in the fumigation of certain types of small mills. The inert material is pressed into waferlike discoids each containing approximately one-half ounce of liquid hydrocyanic acid. These discoids are packed in sealed cans of various sizes, and are sold on the basis of the net content of liquid hydrocyanic acid. The use of this material is not recommended for any but professional fumigators.

When large quantities of discoids are used, it is advisable to chill the cans before fumigating. This will retard the evolution of the gas and thus increase the safety of the operation. If solid carbon dioxide is available, a liberal quantity thrown over the tops of the cans in each open case a few hours before the fumigation will chill the discoids.

The proper number of cans should be placed on each floor to be fumigated, and fumigation should be started on the top floor. One man should open the cans, using a special can opener that makes a clean cut close to the rim, while two or more men take the open cans and scatter the discoids over the floor or among the machinery.

Discoids should not be placed directly on painted or varnished floors or woodwork, for the liquid hydrocyanic acid is likely to injure the finish. A layer of two or three thicknesses of paper will provide adequate protection against any liquid that may ooze from the discoids. When discoids are used, the fumigators are exposed to a certain concentration of the gas while they are opening the cans and distributing the contents. Good gas masks will protect them against breathing poisonous fumes, but there is also some danger from the direct absorption of hydrocyanic acid gas through the skin. The fumigating crew should be large enough so that the distribution of the fumigant will be speedy and no one man will be exposed to the gas for a dangerously long period.

As in the case of liquid hydrocyanic acid, a dosage of 8 ounces per 1,000 cubic feet of space should be used.

After the fumigation and ventilation of the building, the spent discoids and the empty cans can be gathered and disposed of. At the end of a 24-hour fumigation the discoids will not retain more than a trace of hydrocyanic acid.

FUMIGATION WITH CHLOROPICRIN

Chloropicrin is also used as a general fumigant for flour mills, though not so extensively as hydrocyanic acid. It is a colorless or slightly yellowish liquid a little more than one and one-half times as heavy as water. One quart weighs about 3½ pounds. It has a boiling point of 233.6° F. and on exposure to air evaporates slowly, forming a vapor that is about 5 times as heavy as air. The gas is nonexplosive and noninflammable as ordinarily used, and is extremely toxic to insects. It has an irritating effect on the eyes and respiratory passages, which insures against the possibility of anyone accidentally entering a building filled with the gas.

Chloropicrin is marketed in cylinders containing 1, 3, 5, 10, 25, 50, and 100 pounds net. For general fumigation work it is convenient to purchase it in 100-pound cylinders. The cylinders are so arranged that a faucet valve can be attached and the liquid drawn off in any quantity desired (fig. 20).

For fumigation with chloropicrin, a mill is prepared in the same way as for fumigation with hydrocyanic acid gas, but the fumigant is applied in a different manner. Each piece of machinery is treated separately, and in addition the open space of the mill is treated at the rate of 1 pound of chloropicrin per 1,000 cubic feet.

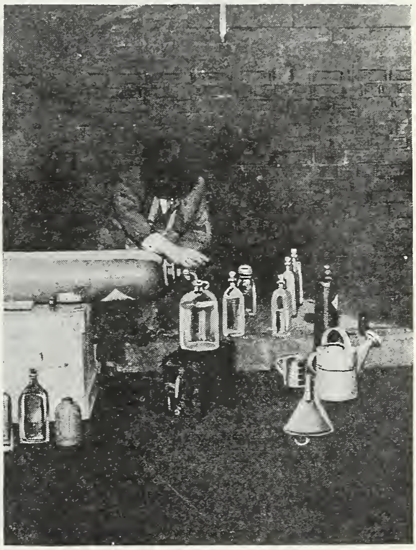

FIGURE 20.—Drawing chloropicrin from cylinder into containers suitable for distributing it throughout the mill.

Sufficient data have not yet been obtained for making definite recommendations of dosages to fit the varying conditions encountered in general mill fumigation. In general, however, the following dosages recommended by the manufacturers of chloropicrin will give satisfactory results:

Dosage Table for Treating Milling Machinery

All bins, including packer bins, feed and bran bins, and screening bins.	1 pound per 1,000 cubic feet of space.
Elevator legs	8–9 ounces each, in upstream side.
All reels, purifiers, dusters, scourers, and conveyors	5–6 ounces each.
Square sifters	2–3 ounces each section.
Rolls	1 ounce each.
Separators	2–3 ounces each.
Flour agitators	2 ounces each.
Grinders for screenings and bran	2 ounces each.
Buhr mill	2 ounces.

The proper quantity of chloropicrin for each floor of the mill should be measured out from the 100-pound cylinders into quart glass bottles or gallon containers and distributed before the fumigation is started. For the comfort of the workers the measuring should be done outside the building so that the fumes will be dissipated in the open air. The quart bottles should be graduated so that the correct dosage for each piece of machinery can be applied quickly. One pound of chloropicrin equals 9¼ fluid ounces.

The fumigators start at the top of the mill and work down, treating all machinery and leaving the elevator boots until the last. Each fumigator must wear a mask equipped with a canister specially adapted to protect against the vapors of chloropicrin.

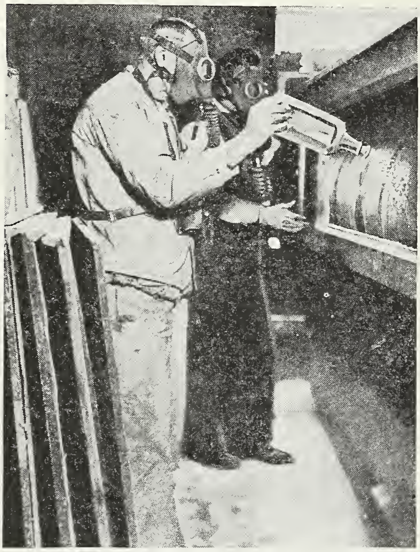

FIGURE 21.—Treating a purifier with chloropicrin.

The machinery is treated by sprinkling it from the quart bottles directly inside each machine (figs. 21 and 22) or, if this is impractical, by pouring it in through a hole bored in one end. Aluminum sprinkler corks can be attached to the quart bottles as they are used. In open mill space the chloropicrin is sprinkled on burlap sacks spread out on the floor, 6-quart sprinkling cans being convenient for this purpose (fig. 23).

Care should be taken not to spatter the liquid on the hands or feet, since blistering of the skin may result.

Where conditions in the mill do not warrant a general fumigation, satisfactory results can sometimes be obtained by fumigating the machinery only. For this type of fumigation the chloropicrin is applied directly into the machines in accordance with the dosage table, and the machines are then closed up. The procedure is the same as in the general mill fumigation, except that the machinery is not dismantled and the clean-up of accumulated flour in the machinery need not be so thorough. The dosage for the reels and purifiers should be increased in proportion to the quantity of stock left in the machinery. In general, at least 1 pound of chloropicrin should be used for each machine.

Considerable time is required to ventilate a building that has been fumigated with chloropicrin, as evaporation is slow and the fumigant clings to fumigated commodities with great tenacity. When present in flour, chloropicrin has a deleterious effect on its baking qualities, but this effect disappears when the flour is aerated.

HEAT AS A MEANS OF CONTROL

The effectiveness of heat in the control of all insects infesting flour mills was first determined as a result of investigations conducted by the senior author from 1910 to 1913. Following experimental work at the Kansas Agricultural Experiment Station, practical demonstrations were conducted in several flour mills in Kansas representative of different types of construction. So successful were these demonstrations that the heat method was thoroughly tested by the Bureau of Entomology, United States Department of Agriculture, and by entomologists in several States, with the result that flour mills in Kansas, Missouri, Ohio, Nebraska, Oklahoma, Illinois, Indiana, Virginia, Iowa, southern Canada, and elsewhere were equipped for using this method. Besides being effective, the heat method has the added advantage of being absolutely safe.

TEMPERATURES NECESSARY

A temperature of from 120° to 125° F. in all parts of the mill for a period of from 10 to 12 hours is sufficient to destroy all insect life. To obtain these killing temperatures in the parts exposed to the radiation, the air should be kept in circulation by means of fans or by running the machinery. The fans should be so located as to keep the hot air moving away from the radiators. Otherwise the temperature in some parts of the mill will be higher than necessary. Steam heat at a pressure of from 25 to 40 pounds per square inch in well-distributed steam pipes is a satisfactory method of obtaining mill temperatures fatal to insects.

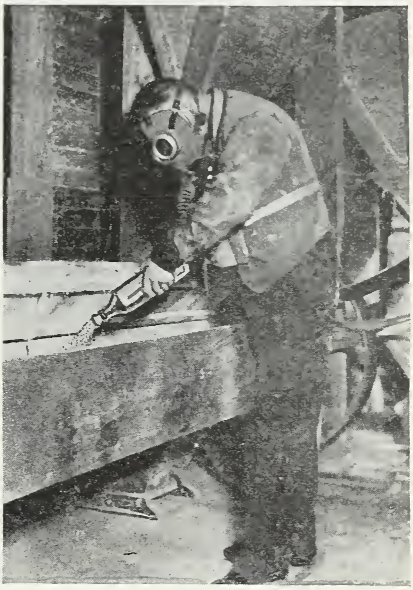

FIGURE 22.—Applying chloropicrin to individual machines of a mill.

MOST EFFECTIVE TIME TO HEAT

To take advantage of the normally high temperatures, it is advisable to apply the heat treatment during the summer months. With summer temperatures of 85° F. or above, less fuel, less radiation surface, and less time are required. It is difficult, and in some buildings almost impossible, to get uniformly good results in windy weather. In frame buildings covered with sheet iron, good results cannot be obtained while it is raining, particularly if it is a light rain lasting for several hours.

RADIATION REQUIRED

The radiation surface required to heat a given space depends on the construction and condition of the building, the number of windows and doors on each floor, the character of the machinery, and the location of the steam pipes. Since these factors vary greatly in flour mills, definite recommendations cannot be given. The engineer of each plant, after 1 or 2 experimental heatings, will be able to regulate the amount of radiation surface in various parts of the mill to obtain the desired temperatures. Usually 1 square foot of radiation will heat from 50 to 100 cubic feet of space. A mill that has sufficient radiation to heat it in winter to a temperature of 70° F. without the friction heat of the running machinery will require only a little additional radiation, if any, to heat it in summer to a temperature of 120°–125°.

For a five-story building 1 square foot of radiation is recommended for each 50, 60, 75, 100, and 110 cubic feet of space for the first, second, third, fourth, and fifth floors, respectively. The amount of radiation surface per linear foot, and the number of linear feet of pipe required to make 1 square foot of radiation surface for pipes of various sizes are shown in table 1. If steam pipe is used for the radiation, 1¼- or 1½-inch pipe is recommended as most practical. Unit heaters capable of supplying any desired amount of radiation can be purchased ready to install.

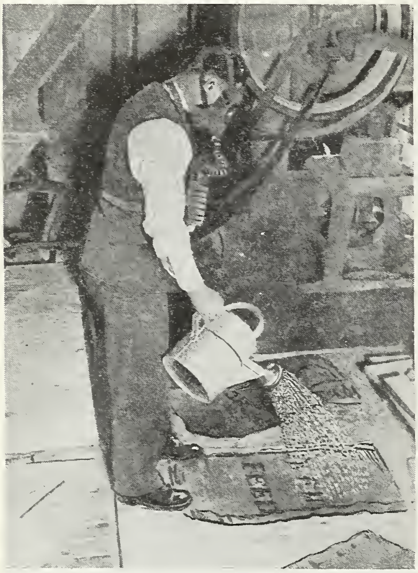

FIGURE 23.—Applying chloropicrin with a sprinkling can to open mill space.

TABLE 1.—*Radiation requirements for fumigation of mills by heat treatment*

Size of pipe	Radiating surface per linear foot	Length of pipe per square foot of radiating surface
	Square foot	*Feet*
1 inch	0.346	2.9
1¼ inches	.434	2.3
1½ inches	.494	2.0
2 inches	0.622	1.6
2½ inches	.753	1.3

EFFECT ON BAKING QUALITY OF THE FLOUR

The question naturally arises as to whether the heat has any deleterious effect on the baking quality of the flour. To obtain data upon this subject, baking tests were made of a patent hard-wheat flour, a low-grade hard-wheat flour, and a pancake flour. These flours were subjected to a temperature several degrees higher than that recommended for treating a mill. The patent and low-grade hard-wheat flours were subjected to 140° F. for 9 hours, and the low-grade flours were again subjected to this temperature 2 and 6 weeks later to ascertain whether a second and a third heating would have an injurious effect. The pancake flour was subjected to 130° for 48 hours. These tests showed that the heat had absolutely no deleterious effect on the baking qualities of the flours.

EFFECT ON MILL EQUIPMENT

In some mills where the heat treatment has been given, the high temperatures have been found to exert a drying effect on the milling machinery, causing some warping and drawing apart of the elevator legs, sifters, purifiers, and reels. Excessive warping can be prevented by maintaining a relative humidity of about 50 percent in the mill. This can be accomplished by the judicious use of steam jets. By directing the steam over the heating coils any condensed water will be vaporized. Care must be taken, however, to prevent the air from becoming saturated, since more heat is required to raise the temperature of saturated air than dry air.

Since heat will cause tight belts to soften and stretch, it is advisable to loosen all belt tighteners, although it is not necessary to remove the belts. Spraying the belts with neat's-foot oil a few days before the heat treatment will keep them in good condition. Grease in boxings melts during the heating process, and it must be replaced before milling operations are resumed.

IMPORTANT POINTS TO BE CONSIDERED IN HEATING A FLOUR MILL

1. The steam pipes should be located near the floor and so arranged as to give an even distribution of heat.
2. There should be traps to draw off all water accumulating in the pipes and radiators.
3. The lower floors and the floors on which there is heavy machinery should have more radiating surface in proportion to the space to be heated than the upper floors and the floors with light machinery.
4. The steam pressure should be from 25 to 40 pounds per square inch.
5. Excessive warping of wooden parts can be prevented by maintaining a relative humidity in the mill of about 50 percent. This can be accomplished by the judicious use of steam jets. Care must be taken, however, to prevent the air in the mill from becoming saturated.
6. Stairways and elevator shafts should be closed to prevent an upward rush of the hot air.
7. Thermometers should be placed at convenient points on each floor.
8. Time must be taken to reach the desired temperature.
9. A temperature of 120°–125° F. is sufficient for any part of the mill.
10. This temperature should be maintained for several hours to allow the heat to penetrate all the infested parts of the mill.
11. Since excessively high temperatures are injurious to machinery, temperatures above 150° F. should be avoided.
12. To keep the air in circulation, fans should be provided on each floor near the radiators, or the machinery should be run at regular intervals.
13. All belt tighteners should be loosened. Belts should be sprayed with neat's-foot oil several days before the mill is heated.
14. A mill should not be given a heat treatment on a windy, cold, or rainy day.

COMBINATION OF HEAT TREATMENT AND FUMIGATION

Where it is difficult to obtain sufficiently high temperatures in the basement, on the roll floor, or in the packing room of the mill, it is suggested that these floors be fumigated with liquid hydrocyanic acid after the temperature reaches 110°–115° F. in these places. The warm, dry atmosphere will not only cause the insects to become more active and run in the open, but it will also give a lethal concentration of gas almost at once.

SUPPLEMENTARY CONTROL MEASURES

PERIODIC REMOVAL AND TREATMENT OF ACCUMULATED MACHINERY STOCKS

In many mills the elevator boots are cleaned out every 2 weeks. This practice aids materially in holding the insect infestation in mill machinery to a minimum. The stock is fumigated or heat-treated before it is fed back into the mill.

Samples of flour taken from machinery in mills where this practice is followed over a long period show a much lower infestation than samples taken from other mills. The cost of this operation is negligible when the great reduction in insect population is considered. The material removed from the elevator boots in one operation amounts to approximately one-half to 1 pound per barrel of milling capacity.

LOCAL FUMIGATION

Many millers resort to local fumigation, that is, fumigation of individual machines, to aid in holding down the infestation between general fumigations. The value of such a practice is questionable, since fumigated machinery is immediately reinfested from other sections of the machinery.

USE OF SPRAYS

A spray, to be effective, must come in contact with the insect against which it is directed. Its use in milling machinery must, therefore, be very limited. Such a spray should be noninflammable and have no deleterious effect on mill products.

INSECT CONTROL IN THE WAREHOUSE

SANITATION

In flour warehouses every precaution should be taken to prevent the development of insect infestation. The floors should be thoroughly swept and all accumulations removed and burned or fumigated in a vault. Freshly milled flour should not be stacked near stocks that have been in the warehouse for any length of time. If separate warehouses are not available for the storing of shorts, bran, and other feed stocks, these materials should be stored in a section well away from those used for flour storage. The older stocks of flour should first be removed as the sales demand.

FUMIGATION

The use of fumigants in warehouses containing large stocks of flour has given varying results and, although dosages as high as 3 pounds of liquid hydrocyanic acid per 1,000 cubic feet of space have been used, a complete kill is rarely obtained. This is because it is extremely difficult for the gas to penetrate to all the bags that are stacked in the warehouse. The gas can only reach the center of a pile of bags by the process of diffusion, and the flour in the outside bags adsorbs so much gas that diffusion to the inner bags is slow.

If the warehouse is tight and the gas can be left in for several days, a certain amount of desorption from the outer bags will take place and the gas will gradually penetrate to all parts of a stock. Obviously, stacking the bags in such a way that the gas can easily reach all of them will greatly increase the effectiveness of the fumigation, since the gas will reach the bags before the concentration has been reduced through leakage from the building and excessive adsorption in the outside bags.

In a fumigation in which a dosage of 3 pounds of liquid hydrocyanic acid was used for a 36-hour period, 100-pound bags of flour were found to adsorb 56.5 parts per million of hydrocyanic acid in the outer layers of flour and 41.5 parts per million in the middle. In the middle of 24-pound bags the flour adsorbed 61 parts per million.

Even though warehouse fumigation is not 100 percent effective, the kill obtained makes fumigation well worth while. The dosage to be used will depend on the tightness of the building and the amount of stock. Reducing stock to a minimum during the summer months, practicing rigid warehouse sanitation, and fumigating once a year will do much to reduce insect losses in the warehouse.

INFESTATIONS OF FLOUR IN TRANSIT

Flour that has been in transit frequently arrives at its destination in an infested condition. This infestation may have been present in the flour before loading. Occasionally, however, there is reason to believe that the flour becomes infested in the railway cars in which it is shipped.

Railway cars that have been used for carrying grain harbor many species of grain-infesting insects. These insects have been found in accumulations of grain in the cracks of the sides and bottom of cars, and especially back of the car lining. Such infestations cannot always be eliminated by merely sweeping out the car, and the only safe procedure is to fumigate it. Unfortunately, the present effective fumigation methods are too costly to be universally practiced. Hydrocyanic acid gas, in dosages of 1½ pounds of liquid hydrocyanic acid or its equivalent, is the most satisfactory fumigant for empty box-car fumigation. Cars that have been fumigated should be well aerated before being loaded with grain or flour, to remove all traces of the fumigant. A representative of the mill should carefully examine all cars before accepting them for loading and refuse to accept any car that shows evidence of infestation.

Serious infestations of flour have developed during the period of storage on docks awaiting shipment. Such infestations have usually been due to the storage of flour in close proximity to infested material, such as rice and cottonseed meal. Certain berths should be assigned to storage of flour, and these berths should be well separated from stores of foodstuffs likely to harbor insects.

The use of concrete floors on wharves is desirable, since wooden floors often afford hiding places for large numbers of insects. Straw or wooden mats should always be used as dunnage under the flour, and under no conditions should rice hulls be used.

Passage on ships frequently affords opportunity for infestation of flour both from the ship itself and from storage of infested commodities in the same hold. The dunnage is frequently infested. Slow voyage and warmth in the hold offer ideal conditions for insect development. Insects frequently migrate from infested food products or grain in one compartment to flour in the same hold. Flour should never be used as dunnage for grain. Ships carrying flour and grain should be inspected regularly, and fumigated with hydrocyanic acid if found to be infested.

INSECT CONTROL IN RETURNED GOODS AND USED BAGS

FUMIGATION IN VAULTS

Many mills have use for a small fumigation vault in which to treat returned goods and used bags. Such a vault may be constructed of any material that can be made gastight.

Several types of metal vaults can be purchased in the knocked-down state ready for assembling. These are excellent in every way. Highly satisfactory vaults can be constructed of concrete, brick, or hollow tile. The brick and hollow-tile vaults should be finished inside with a layer of Keen's cement and one or two coats of paint. Wooden vaults with a metal lining are also popular. Fourteen-gage sheet metal can be purchased cut up into sections for lining a vault 8 by 10 by 12 feet, and, when welded together, these form an excellent gastight lining.

All types of vaults should be equipped with a refrigerator or safe type of door, well gasketed to make it gastight.

A ventilating system capable of quickly removing the fumigant from the vault after the fumigation is essential. If the vault is set up inside a building, the ventilating stack must extend outside the building.

It is frequently desirable to install an electrical heating unit controlled by a thermostat, so that a constant high temperature can be maintained throughout the fumigation.

Hydrocyanic acid, chloropicrin, and the ethylene oxide-carbon dioxide mixture are all suitable for vault fumigation, and they can be used in the same manner as described for the fumigation of large spaces. The dosage will depend on the type and quantity of material in the vault. If hydrocyanic acid gas is used, the barrel or pot method or the liquid method can be utilized. Chloropicrin can be applied by pouring the proper quantity into an evaporating pan, or by sprinkling. The ethylene oxide-carbon dioxide mixture is usually applied through a piping system and can be administered by merely connecting the cylinder to the system and opening the valve. If the cylinder is placed on a platform scale, it is an easy matter to let in the right quantity.

USE OF HEATING ROOMS

The installation of a heating system in a small, tight room or vault provides an excellent means of treating returned products and second-hand bags. Twenty-two square feet of radiation per 100 cubic feet of vault space has been found sufficient to produce the proper temperature for sterilization. In one such vault a 30-hour exposure of 100-pound bags of flour killed all insect life. The bags were arranged on racks so that no two were in contact with each other (fig. 24).

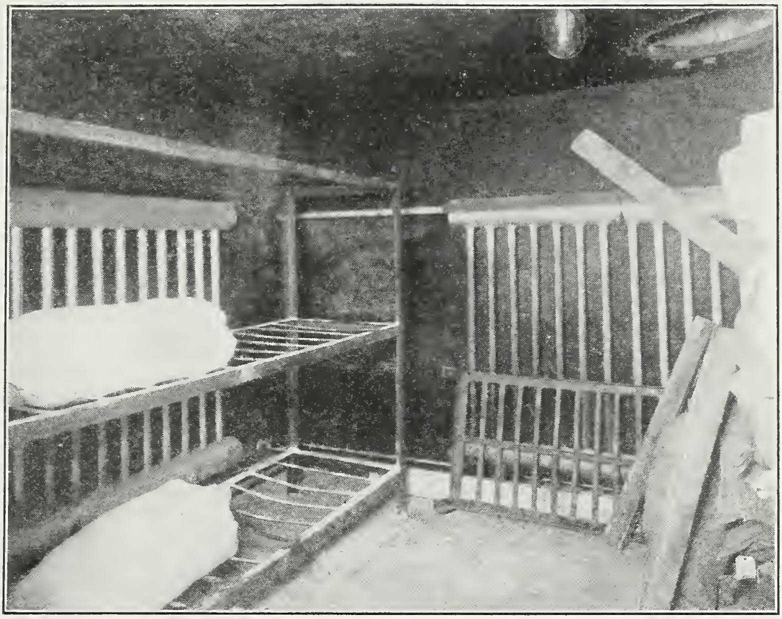

FIGURE 24.—Interior of vault used for treating flour products with heat or fumigants. Note racks used for separating the bags of flour to facilitate penetration.

RAILWAY-CAR FUMIGATION

When no vault is available, it is often necessary to fumigate returned stock, second-hand machinery, and returned bags in railway cars. A dosage of 6 pounds of liquid hydrocyanic acid or its equivalent has given satisfactory results in cars loaded with second-hand machinery. This high dosage is necessary because in all railway cars there is some leakage. In cars loaded with flour or second-hand bags, the high adsorption capacity of the flour prevents the hydrocyanic acid gas from penetrating into the lower tiers of bags.

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